Impact of opening a new emergency department on healthcare service and patient outcomes: Analyses based on linking ambulance, emergency and hospital databases

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ABSTRACT

Objective: To investigate the impact of opening a new Emergency Department (ED) on patient and regional health care service outcomes.

Design: Data from three separate health information system databases (ambulance, ED and hospital admission) were deterministically linked. A 24 month time series analysis was employed to determine changes in service delivery and patient outcomes at three public hospitals within the region.

Sample and Setting: 285,463 ED presentations, 80,194 ambulance arrivals and 67,941 hospital admissions, made to three regional public teaching hospitals in Queensland, Australia, over a 2-year period (September 3, 2006 to September 2, 2008).

Main outcome measures: Ambulance (ambulance offload time exceeding 30 mins), ED (ED length of stay, LOS) and hospital (percent of access block) outcome measures.

Results: The total volume of ED presentations increased approximately 18% within the region, while local population growth increased by only 3%. Healthcare service and patient outcomes at the two pre-existing hospitals (A and B) within the area did not improve. These outcomes included ambulance offload time: (Hospital A PRE: 10mins, POST: 10mins, $p<0.001$; Hospital B PRE: 10mins, POST: 15mins, $p<0.001$); ED LOS: (Hospital A PRE: 242mins, POST: 246mins, $p<0.001$; Hospital B PRE: 182mins, POST: 210mins, $p<0.001$); and access block: (Hospital A PRE: 41%, POST: 46, $p<0.001$; Hospital B PRE: 23%, POST: 40%, $p<0.001$). Time series modelling indicated that the effect was worst at the hospital furthest away from the new ED.

Conclusions: There is an inherent need to take a 'whole of hospital' and 'whole of health service area' approach to solve crowding issues. Our data indicated that an additional ED within the region saw an increase in the total volume of ED presentations at a rate far greater than local population growth, suggesting it either tapped into a previously unmet need within the local community or resulted in a shifting of activity from one sector to another. While a new ED could ease the pressure on workload, careful monitoring by appropriate health care service planners is vital, as the dynamics of health care delivery are multifaceted.

INTRODUCTION

Emergency department (ED) and hospital crowding is an increasingly common issue facing today's acute health care services throughout the world.[1-9] Overcrowding refers to the situation where ED function is impeded, primarily because the number of patients waiting to be seen, undergoing assessment and treatment, or waiting for admission or discharge, exceeds the physical or staffing capacity of the ED.[10] Negative outcomes to patients, health care organisations and communities have been associated with overcrowding and related issues such as access block and ambulance diversion.[2,3,9,11]

International,[12,13] national[14] and state[15,16] organisations recognise that improvements in or expansions of health care related services are required in order to meet the health care needs of the community in a safe and sustainable fashion. A variety of interventions designed to improve the timeliness of care that target the input, throughput or output aspect of the patient journey have been described.[17] A number of these and other measures have been implemented in some Australian EDs with varying degrees of success. Examples include: the employment of advanced practice nurses for specialist roles such as discharge planning,[18,19] clinical initiatives nurse at triage,[20] early pregnancy management,[21] nurse practitioners,[2,23] nurse initiated protocols/guidelines,[4] physician staffing at triage,[5,26] rapid assessment teams,[7,28] fast track areas[29,30] and observation/short stay wards.[31] These measures however, have not been enough to sustain an effective flow through the acute health care system. As such, it has become increasingly evident that 'whole of hospital',[7,11,32-34] 'whole of health service area'[4,34,35] and whole-of-system[14,33,36,37] approaches are necessary to overcome issues related to increasing patient volumes.

One strategy aimed at alleviating the influx of patients into an overcrowded hospital system is to close the ED i.e., shut it down altogether, or on a temporary basis to ambulance traffic.[3,38] This strategy, on the whole, is sub-optimal for patients as treatment delays and in some cases death can result.[3,38] Furthermore, when ambulance diversion occurs at one ED, it often causes crowding and subsequent diversion at nearby facilities.[3,39] This has been referred to as the 'network effect'.[3]

Other approaches directed towards alleviating pressures of increasing patient volumes and overcrowding are to open an additional ED or expand the size and number of beds in an existing ED. Very little literature exists on the impact these measures make to service delivery and patient outcomes. Literature available regarding opening new or expanded EDs are mainly descriptive[11,40,41] with some before and after measured outcomes[11,32] and discussions on 'lessons learnt'.[40-42] The two studies with pre and post new/expanded ED data identify increases in both patient volume and average ED LOS for all presenting patients. Despite the increased volume, outcomes that reportedly improved included patient and staff satisfaction, decreased staff turnover[11] and decreased did not wait rates.[32] The findings of these studies differed regarding whether the new/expanded ED impacted on ambulance diversion. One found it decreased,[11] the other found it did not change.[32] Although it is unclear whether additional ED beds alone can alleviate overcrowding, consistently noted is the requirement that other bottlenecks in the hospital system (beyond the ED) are also addressed,[11,32,42,43] either prior to, or along with, the expanded ED capacity.

Previous US studies that discuss opening new/expanding EDs have mainly focussed on outcomes from acute care provision facilities (Level I and II trauma centres). The US has different health funding systems and level of care provisions to those of Australia. The purpose of this study was to examine the impact on patient and health service outcomes for surrounding hospitals and ambulance services in the 12 months before and after an additional ED was opened in South East Queensland, Australia by deterministically linking three databases: ambulance, ED and hospital.

METHODS

Design

Comparative and time series design was used in this study to identify changes in patient, health care organisation and ambulance service outcomes by linking data from three major health service data systems that capture information related to a patient's acute care journey including ambulance transport +/- ED attendance +/- hospital admission. Data were obtained from the Decision Support Service unit of each hospital and Queensland Ambulance Service (QAS).

Approval to conduct this study was obtained from the Human Research Ethics Committees of participating sites and ambulance service as well as Queensland Health's Research Ethics and Governance Unit (REGU) in order to access public health records.

Sample and Setting

The study sample consisted of patient presentations made to three South East Queensland public teaching hospital EDs between September 3, 2006 and September 2, 2008. The two pre existing hospitals were located within a 60 km radius of the new ED. The closest (Hospital A) was located 15 km from the new ED. Hospital A was a 473 bed tertiary referral centre; the ED consisted of 31 acute care beds, 10 observation ward beds and 4 fast-track beds. The next closest hospital (Hospital B) was located 58 km from the new ED. Hospital B was a 290 bed urban hospital; the ED consisted of 22 acute care beds, 10 observation ward beds and 4 fast-track beds. Hospital C (where the new ED was opened) was an urban 200-bed hospital that did not have an ED until September 3, 2007; the new ED consisted of 25 beds, 12 observation ward beds and 4 fast-track beds. The QAS transported patients to these and other EDs within the region. These three public hospitals, along with 3 private hospitals, served a total population of approximately 800,000.[44]

Data Collection

Data obtained were based on a previous conceptual framework of ED crowding,[5] predictors associated with crowding, ambulance diversion and in-hospital mortality literature together with discussions with expert personnel with an ED, research or ambulance background. The use of databases for research is a popular method for examining the distribution and determinants of health-related states or events in specified populations.[46] The Decision Support Service unit of each hospital and the QAS provided the routinely collected data from the following health information systems: Emergency Department Information System (EDIS), Hospital Based Corporate Information System (HBCIS), and electronic Ambulance Record Form (eARF). EDIS is the software used within most Australian public EDs. It records and stores information on each patient's ED episode. HBCIS is the inpatient administration system used within Queensland public hospitals. It contains patient demographic information as well as information regarding each patient's hospital admission episode. The eARF is the QAS record of information on each patient's ambulance episode. Data collected from each health information system for this study included: EDIS: medical unit record (UR) number, name, date of birth, sex, post code, reason for ED presentation (ICD code), mode of arrival, Australasian Triage Scale (ATS), date of presentation, time of presentation, time of departure from ED, discharge destination from ED; HBCIS: UR, name, date of birth, sex, post code, time of admission, date of admission, Diagnostic Related Group (DRG), date of hospital discharge, discharge destination, in-hospital mortality; QAS: Name, age, sex, post code pick up, suburb pick up, triage code allocated by the Communications Centre, suburb location of base station, date of transport, time of dispatch, time of arrival to dispatched site, time of departure from dispatch site, time of arrival to ED, time of triage by ED staff, time of stretcher off-load, off-load destination.

The ATS is a tool used as an indicator of clinical urgency.[47] It is measured on a scale of 1 to 5, where 1 is the most urgent. ED LOS was calculated from ED arrival and departure time.[47] Ambulance offload time > 15 minutes[48] and > 30 minutes were calculated from the QAS data from arrival at ED and stretcher offload time. Access block was calculated for patients requiring hospital admission where ED LOS was 8 or more hours.[10]

We used Health Data Integration (HDI), an automated deterministic linking approach developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to link data from the three separate health information system databases (QAS, EDIS and HBCIS). The HDI linking strategy has previously been tested on this type of data for accuracy with high sensitivity, specificity and positive predictive value (PPV) yields.[49] Compared with a manual linkage approach, HDI linkage results were as follows: Ambulance – ED linkage had a sensitivity of 95.5%, a specificity of 99.6% and a PPV of 87.9%; the ED – hospital admissions linkage had a sensitivity of 99.0%, specificity of 74.9% and PPV of 95.0%. The HDI linking strategy was based on patient name, age (+/- 5 years), sex, date and time of arrival and date and time of admission (if admitted).

Statistical Analysis

Descriptive statistics were used to describe the profile of all patients presenting to three EDs within South East Queensland. These statistics included measures of central tendency, such as median and inter-quartile range for age and time variables. Frequency distributions were used for categorical variables. Specifically, percentages were calculated for patients who arrived by ambulance, had an ambulance offload time of > 15 and > 30 minutes, were admitted, were access blocked, and for those who died in hospital. Inferential statistics were used to identify differences between groups. Groups were viewed as independent from each other.[50] Statistical methods employed for testing differences between groups included Mann-Whitney U tests (for continuous data with skewed distribution including age and time variables) and chi-square tests (for categorical variables including age group, sex, day presented, season, triage category, admission, DRG and mortality). Using daily time points (i.e. 365 pre and post time points), times series analysis (using ARIMA modelling)[51] was performed for site A and B to test for any significant change in three outcome measures: the percentage of presentations for ambulance offload time > 30 minutes, ED LOS, and percent of access block following the opening of the new ED. Data management and statistical analyses were conducted using SPSS software, version 17 (SPSS Inc, Chicago, Ill, USA) and R.[52] Significance for all results was defined as $p < 0.05$.

RESULTS

The sample/data inclusion flow diagram is presented in Figure 1. Total ED attendances in the district increased 18.4% during the study period from late 2006 to 2008. A combined total of 119,459 patient presentations were made to the EDs of Hospital A and B in the 12 months following Hospital C's ED opening. A total of 35,287 patient presentations were made to the new ED (Hospital C) during its first 12 months. Whilst the total number of ED presentations increased with the addition of the new ED within the region, numbers decreased at the EDs of Hospital A and B. Demographic characteristics for patient presentations made to each site are presented in Table 1. Age and sex differences did not vary greatly at each site from one year to the next; the median age was around 30 years and males represented between 50% and 53%.

INSERT TABLE 1 ABOUT HERE

ED characteristics for patient presentations made to each site are presented in Table 2. For Hospital A and B, when the year prior to the new ED opening was compared to the year post, significant differences for the characteristics: mode of arrival, triage category, reason for presentation and season were identified. For Hospital A, lower proportions of ambulance arrivals, ATS 3 presentations, several presenting complaints as well as autumn presentations occurred in the 12 months following the new ED opening. For Hospital B, lower proportions of ambulance arrivals, ATS 4 and ATS 5 presentations, several presenting complaints as well as autumn and winter presentations occurred in the 12 months following the new ED opening. The majority of ED characteristics for patient presentations made to Hospital C (with the new ED) closely reflect the other sites (during post year). There were however, lower proportions of ambulance and police arrivals, ATS 1 and ATS 3 presentations, non-emergent reviews, cardio-vascular presentations and higher proportions of walk-in and ATS 5 presentations.

INSERT TABLE 2 ABOUT HERE

Ambulance, ED and hospital admission outcomes are presented in Table 3. For Hospital A, when the year prior to the new ED opening was compared to the year post, significant differences for QAS outcomes (median offload time, median time to triage, offload delay exceeding 15 mins, ED LOS for ambulance arriving patients); ED outcomes (time to see a doctor, median ED LOS, ED LOS exceeding 4 hours, ED LOS exceeding 8 hours, admission requirement); and hospital admission outcomes (median ED LOS for admitted patients, access block at 8 hours, in-hospital mortality) were identified. For Hospital A, in the 12 months following the new ED opening, higher proportions of all aforementioned outcomes were noted, except for in-hospital mortality which decreased (pre 3.0% vs. post 2.2%, $p<0.001$).

For Hospital B, when the year prior to the new ED opening was compared to the year post, significant differences for all QAS outcomes (median offload time, median time to triage, offload delay exceeding 15 mins, offload delay exceeding 30 mins, ED LOS for ambulance arriving patients), all ED outcomes (time to see Dr, median ED LOS, ED LOS exceeding 4 hours, ED LOS exceeding 8 hours, admission requirement) and all hospital admission outcomes (median in-hospital LOS, median ED LOS for admitted patients, access block at 8 hours, in-hospital mortality) were identified. For Hospital B, in the 12 months following the new ED opening, higher proportions of all aforementioned outcomes were noted, except for in-hospital mortality which decreased (pre 2.7% vs. post 1.9%, $p<0.001$).

INSERT TABLE 3 ABOUT HERE

Time series analysis (using ARIMA modelling) was performed to evaluate if the new ED that opened in September 2007 had any significant impact at sites A and B on the following three outcomes: offload time > 30 minutes (figure 2), ED LOS (figure 3), and access block (figure 4). After accounting for the cyclic, seasonal and long term trend changes we tested if the opening of the new ED had a significant effect on the series. Table 4 presents summary data from these models. There was a significant increase in access block at Hospital A and no significant impact on offload time or ED LOS after Hospital C opened a new ED. All indicators were significantly elevated in Hospital B (furthest from the new ED) after the new ED opened.

INSERT FIGURE 2, 3 and 4 ABOUT HERE

INSERT TABLE 4 ABOUT HERE

DISCUSSION

Growth

This study was set within the context of an increasing acuity[1,53,54] and patient presentation numbers to EDs[6,7] with a fixed number of hospital beds and limited number of ambulance resources. The total volume of ED presentations in our study increased approximately 18% within the region, despite local population growth of only 3.1%.[55] This increase in ED presentations is higher than the 11.5% growth in presentations following the opening of a new ED in the US in 2004[11] and higher than the annual increase of ED attendances within Australian and Queensland public EDs; 5.1% and 6.4%, respectively from 2006/2007 to 2007/2008.[56, 57]

Clinical importance

Our main findings indicate that opening a new ED alone (i) did not improve overcrowding issues such as ambulance off-load time, ED LOS and access block at the hospital closest (Hospital A), (ii) did improve in-hospital mortality rates, and (iii) had a strong effect at the hospital furthest away (Hospital B). The first finding is consistent with other reports describing the effect of new/expanded EDs opening in the US. One study describing the effect of a new 96 room + 2 trauma bay ED reported increases in patient volume (by 11.5%), admission rate (from 27% to 29%) and average ED LOS for all patients (from 4 to 4.5 hours) and admitted patients (from 6.5 to 7.5 hours).[11] Other reported outcomes that improved were patient and staff satisfaction, decreases in staff turnover and decreased need for ambulance diversion.[11] These latter outcomes were not accompanied with pre measures so it is difficult to interpret these findings. Another, more recent before and after study, examined the effect of an ED expansion (from 28 to 53 beds) in the US on ambulance diversion.[32] Results from that study identified an increase in patient volume, but no significant change in time spent in the ED or number of ambulance diversions (approx 2) per month. Additionally, total and admission hold time (time waiting for ward bed) increased (total admission time: pre: 4.6 to post: 5.6 hours; time waiting for an admission bed: pre: 3 to post: 4.1 hours).[32] The new/expanded EDs described in previous reports were from facilities in the US from Level I and Level II trauma centres. Health care systems in the US differ to those in Australia, in terms of specialisation of services and funding arrangements. These factors make further comparisons with these studies and settings difficult.

The second main finding indicates that despite worsening ED and hospital outcomes, the mortality rate dropped from one year to the next at both hospitals. In-hospital mortality rates in our study sites were slightly higher than the national average of 1.3%.[57] It may be that the reduction in overall numbers admitted to Hospitals A and B via the ED allowed for a more 'holistic' care focus that resulted in a lower mortality rate in the year after the new ED opened. There is also the possibility that with such short in-hospital LOS (2 days in our study, vs 6.5 days for all Australian public hospitals, excluding same day separations),[57] some people were discharged too early, died at home and were not captured in this study.

The third main finding (worse outcomes at the hospital furthest away) has not, as far as we are aware, been described in the literature in the context of a new ED opening. We purport that had the new ED not opened, Hospital A (the closest hospital) would have followed similar trends to Hospital B and outcomes might have been worse. It could be suggested that opening the new ED at Hospital C had a 'stabilisation effect' on Hospital A during the first year of the new ED's operation. Interestingly, demand outgrowing additional ED capacity within one year of opening has been mentioned elsewhere.[41]

Implications

There are several implications pertaining to practice and policy that arise from this study.

Practice Implications

(i) Address work practices to meet evidenced-based clinically relevant endpoints

Contemporary conceptions of overcrowding suggest that overcrowding in the ED reflects broader hospital issues and inefficiencies in bed and resource management.[9,58] The opportunity of building a new ED should therefore be accompanied by an analysis of how work practices currently operate and how they need to change to meet future requirements.[42] One example is correctly defining access block and ED overcrowding so that the problem may be recognised and addressed by those outside the ED, with strong support from hospital managers and decision makers.[4,7,11,32-37] Since commencing this study, a review of the literature has been conducted that identified clinically relevant endpoints of ED overcrowding, based on six IOM (Institute of Medicine) domains: safety, timeliness, patient-centeredness, efficiency, effectiveness, and equity.[58] High quality care should perform well across all six domains. Whilst we measured outcomes within four of the domains: safety, effectiveness (mortality and time related measures), efficiency and timeliness (time related measures) identified by Bernstein et al.,[58] we did not measure other outcomes within the domains (walkouts, time to antibiotic, time to thrombolysis, time to analgesia, satisfaction, healthcare disparities). Even though ED LOS did not improve following the new ED opening, with the hiatus in ED patient volume and subsequent numbers of hospital admissions at each site, in-hospital mortality rates improved across the region. In times of overcrowding, outcomes such as those mentioned by Bernstein et al.[58] have been shown to worsen.[2,59-62] The ability to collect and report on these outcomes should be used to influence strategies for process and patient outcome improvement. Methods facilitating the collection and reporting of the other domains identified by Bernstein et al.[58] and indicators mentioned by others[6, 63] that focus on care quality and safety should be explored.

(ii) Volume must be met with capacity

Increased growth needs to be met with increased capacity. Expanding the capacity to admit patients who present to EDs is one of the major challenges in dealing with overcrowding.[64] Codde et al.[35] and Han et al.[32] attest that even the most efficient ED cannot do any better if the volume and complexity of presentations increase and inpatient beds are not available to enable transfer out of the ED. This notion is reflected in the finding that at each of the three hospitals in this study, the median in-hospital LOS (2 days) was lower than the Australian average for patients admitted to public acute hospitals (3.7 days, or 6.5 days excluding same day separations).[57] Despite this short hospital LOS, each facility was still faced with an increased requirement for hospital admissions as reflected in the increase of access block in the year after the new ED opened.

The level of access block experienced in the year after the new ED opened at Hospital A, B and C was 46%, 40% and 42%, respectively. This is over two and half times higher than the access block of 16% identified by Fatovich et al.[65] at the Royal Perth Hospital. This is a concerning finding for these hospitals and the wider community and is possibly reflective of a lack of inpatient bed numbers that accompanied the new ED opening. The high level of access block has implications beyond the immediate crowding effect. For example, a US study showed an increased mortality rate (of 2%) and longer hospital LOS (of around 3 additional days) for patients boarded in the ED for more than 12 and 24 hours, respectively.[66] An Australian study indicated that hospital and ED crowding has been linked to increased risk of 2, 7 and 30 day mortality with statistically significant hazards ratios of 1.3, 1.3 and 1.2 respectively.[61] A more crowded ED has implications for the ability of a hospital to deal with surge capacity.[58] The American College of Emergency Physicians (ACEP) defines surge capacity as the ‘‘health care system’s ability to manage a sudden or rapidly progressive influx of patients within the currently available resources at a given point in time.’’[64] For these reasons, whole of hospital and health service area approaches are needed to manage crowding issues.

Policy Implications

(i) Meeting strategic needs

The health of people is always a national priority.[12] One of the four Queensland Health strategic priorities is to meet Queenslanders’ heath care needs safely and sustainably.[15] Measures to meet this priority include expanding hospital and related services to meet the growing need of the community. Opening the new 30 bed ED in 2007, additional hospital beds in 2011 and a new 750 bed hospital in 2012, are three examples of an investment in the implementation of Queensland Health’s Strategic

Plan in South East Queensland region alone. Within Australia, the Government (through the National Partnership Agreement) has committed to provide funding exceeding $3 billion for new sub acute beds, to meet emergency department and elective surgery targets and for capital and recurrent projects to improve access for patients accessing public hospital services.[14] Regarding the National Emergency Access Target (NEAT), it is expected that, following a staged annual increase, by 2015, 90% of ED presentations should be admitted, transferred or discharged within four hours.[14] In meeting these targets, the impact of additional beds and services in their much anticipated ability to provide more specialised and extensive health care to the surrounding community warrants evaluation.

(ii) Utilisation of information technology to inform clinical and policy decisions

The value of linked datasets is growing in its ability to inform population-based health research.[67] The ability to link patient level data across three disparate health information systems for three hospitals and the state's Ambulance Service allows for further insight and abilities to explore health care indicators and outcomes that are evidence based and clinically orientated. With the national and state eHealth strategy directed towards the advancement of the collection, transmission, storage and access of patient and clinical information in a way that more effectively supports the clinical care process[15] this research is timely. This research lends itself to further linkage expansions incorporating other health information systems that exist within hospitals and communities. This would allow for further understanding of the patients health care journey that can be utilised to inform diagnosis, treatment and policy decisions.

RECOMMENDATIONS

Based on the practice and policy implications discussed, future research should not only investigate changes in patient and service related outcomes but also explore and describe factors surrounding met or unmet service need with the use of geo-coding mapping and analysis. This is needed to understand where patients travel from to reach their chosen hospital and account for economic and service delivery implications. Future studies should also examine patient decision making practices regarding reasons for presenting to a new or pre-existing ED as well as evaluations of other service delivery initiatives aimed at improving workload practices.

LIMITATIONS

Several limitations pertain to this study. First, this study was limited to the impact on the two pre-existing public hospitals and did not include the effect on the three smaller private hospitals within the region. This option was considered at study inception, however data capture differences would not have enabled analysis for these private facilities. Also, the recognised health service network within the region consists of 10 public hospitals. There may have been a network effect that extended beyond the two sites included in this study. Second, this was a retrospective analysis of prospectively collected data. There may have been inaccuracies within the data provided, however data cleaning measures were implemented. Third, due to the large volume of data analysed, statistical significance may not necessarily relate to clinical significance. Given that not all outcomes were significant indicates that sample size was not however the only factor determining significance. Fourth, our study was limited to the impact of opening additional ED beds only. Because no accompanying hospital beds were opened at the same time, the interpretation of our findings should consider this fact. This is however, perhaps the first study that assesses the health care delivery outcomes using linked population based data bases in Australia to examine the effect of a new ED opening as most of the previous such assessments were reported from the US.

CONCLUSION

The aim of this study was to investigate the impact of opening a new ED on patient and regional health care delivery systems outcomes. Our data indicated that an additional ED within the region saw an increase in the total volume of ED presentations at a rate far greater than local population growth, suggesting it either tapped into a previously unmet need within the local community or resulted in a shifting of activity from one sector to another. While a new ED could ease the pressure on workload, careful monitoring by appropriate health care service planners is vital as the dynamics of health care delivery changes occur in a geographical region may not be a simple equation. We support the inherent need to take a ‘whole of hospital’ and ‘whole of health service area’ approach to solving crowding issues.

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Table 1. Demographic characteristics of ED patient presentations, by site and year

Characteristic	**Hospital A**			**Hospital B**			**Hospital C**
	Pre	Post	P value	Pre	Post	P value	Post
	N= 69,105	N=61,125		N= 61,612	N=58,334		N= 35,287
Median age [IQR]	32 (19-54)	31 (19-52)	<0.001	30 (16-50)	30 (16-50)	<0.001	32 (17-53)
Sex			0.96			<0.001	
Male	36,669 (53.1%)	32,443 (53.1%)		31,681 (51.4%)	29,170 (50.0%)		18,131 (51.4%)
Female	32,436 (46.9%)	28,682 (46.9%)		29,931 (48.6%)	29,164 (50.0%)		17,156 (48.6%)

Table 2. ED characteristics of patient presentations, by site and year

Characteristic	Hospital A			Hospital B			Hospital C
	Pre	Post	P value	Pre	Post	P value	Post
	N= 69,105 (%)	N=61,125 (%)		N= 61,612	N=58,334		N= 35,287
Mode of arrival			<0.001			<0.001	
Walked in	44,401 (64.3%)	40,561 (66.4%)		41,011 (66.6%)	39,354 (67.5%)		27,536 (78.0%)
Ambulance	24,011 (34.7%)	19,675 (32.2%)		20,310 (33.0%)	18,612 (31.9%)		7,602 (21.5%)
Police	646 (0.9%)	815 (1.3%)		262 (0.4%)	320 (0.5%)		120 (0.3%)
Other	47 (0.1%)	74 (0.1%)		29 (0.0%)	48 (0.1%)		29 (0.1%)
Triage category			<0.001			<0.001	
1	563 (0.8%)	665 (1.1%)		307 (0.5%)	385 (0.7%)		93 (0.3%)
2	8,182 (11.8%)	8,021 (13.1%)		4,231 6.9%)	4,786 (8.2%)		3,549 (10.1%)
3	35,502 (51.4%)	30,258 (49.5%)		26,747 (43.4%)	27,426 (47.0%)		15,972 (45.3%)
4	21,866 (31.6%)	19,663 (32.2%)		26,134 (42.4%)	22,755 (39.0%)		13,354 (37.8%)
5	2,992 (4.3%)	2,517 (4.1%)		4,193 (6.8%)	2,982 (5.1%)		2,319 (6.6%)
Day of Week			0.68			0.56	
Monday	10,310 (14.9%)	9,200 (15.1%)		9,399 (15.3%)	8,912 (15.3%)		5,461 (15.5%)
Tuesday	9,561 (13.8%)	8,470 (13.9%)		8,665 (14.1%)	8,298 (14.2%)		4,895 (13.9%)
Wednesday	9,366 (13.6%)	8,124 (13.3%)		8,472 (13.8%)	7,943 (13.6%)		4,760 (13.5%)

Thursday	9,342 (13.5%)	8,197 (13.4%)		8,086 (13.1%)	7,835 (13.4%)		4,689 (13.3%)
Friday	9,652 (14.0%)	8,676 (14.2%)		8,500 (13.8%)	8,056 (13.8%)		4,837 (13.7%)
Saturday	10,172 (14.7%)	8,932 (14.6%)		8,876 (14.4%)	8,357 (14.3%)		5,164 (14.6%)
Sunday	10,702 (15.5%)	9,526 (15.6%)		9,614 (15.6%)	8,933 (15.3%)		5,481 (15.5%)
Season			<0.001			<0.001	
Summer	17,322 (25.1%)	15,513 (25.4%)		14,867 (24.1%)	15,848 (27.2%)		8,612 (24.4%)
Autumn	17,730 (25.7%)	15,053 (24.6%)		15,803 (25.6%)	13,376 (22.9%)		9,425 (26.7%)
Winter	16,940 (24.5%)	15,218 (24.9%)		15,839 (25.7%)	13,914 (23.9%)		10,056 (28.5%)
Spring	17,113 (24.8%)	15,341 (25.1%)		15,103 (24.5%)	15,196 (26.0%)		7,194 (20.4%)

Table 3. Ambulance, ED and Hospital outcomes, by site and year

Outcome	Hospital A			Hospital B			Hospital C
	Pre	**Post**	**P value**	**Pre**	**Post**	**P value**	**Post**
QAS Outcomes	**N= 20,681**	**N= 17,059**		**N= 18,245**	**N= 17,156**		**N= 7,053**
Median [IQR] time to triage (mins)	5.0 (2-9)	4.0 (2-8)	0.045	2.0 (1-4)	3.0 (1-5)	<0.001	4.0 (2-7)
Median [IQR] offload time (mins)	10.0 (5-17)	10.0 (6-18)	<0.001	10.0 (5-18)	15.0 (8-32)	<0.001	11.0 (7-15)
Offload Delay (>15 mins time of arrival to stretcher offload) n (%)	5,835 (28.2%)	5,209 (30.5%)	<0.001	5,460 (29.9%)	8,233 (48.0%)	<0.001	1,757 (24.9%)
Offload Delay (>30 mins time of arrival to stretcher offload) n (%)	1,674 (8.1%)	1,421 (8.3%)	0.410	2,493 (13.7%)	4,444 (25.9%)	<0.001	258 (3.7%)

Median [IQR] ED LOS (mins)	311.0 (187-495)	336.0 (203-549)	<0.001	231.0 (145-357)	286.0 (171-483)	<0.001	311.0 (191-520)
ED Outcomes	**N= 69,105**	**N= 61,125**		**N= 61,612**	**N= 58,334**		**N= 35,287**
Median [IQR] time to see Dr (mins)	50.0 (17-113)	55.0 (20-126)	<0.001	56.0 (23-114)	65.0 (27-124)	<0.001	39.0 (17-85)
Median [IQR] ED LOS (min)	242.0 (137-399)	246.0 (139-415)	<0.001	182.0 (107-288)	210.0 (122-347)	<0.001	192.0 (113-321)
ED LOS > 4 hrs n (%)	34,754 (50.3%)	31,281 (51.2%)	0.002	21,054 (34.2%)	24,955 (42.8%)	<0.001	13488 (38.2%)
ED LOS > 8 hrs n (%)	12,283 (17.8%)	11,871 (19.4%)	<0.001	4,613 (7.5%)	8,442 (14.5%)	<0.001	4,499 (12.8%)
Admitted to hospital n (%)	19,313 (27.9%)	18,314 (30.0%)	<0.001	11,800 (19.2%)	12,587 (21.6%)	<0.001	8,075 (22.9%)
Hospital Admission Outcomes	**N= 18,876**	**N=17,512**		**N= 11,462**	**N=12,230**		**N= 7,861**
Median [IQR] hospital LOS (days)	2 (1-5)	2 (1-5)	0.151	2 (1-5)	2 (1-5)	0.005	1 (1-4)

Median [IQR] ED LOS (mins)	420 (288-627)	451 (303-672)	<0.001	325 (222-466)	411 (267-627)	<0.001	420 (289-665)
ED LOS (>8hrs) "Access Block" n (%)	7,690 (40.7%)	7,998 (45.7%)	<0.001	2,657 (23.2%)	4,920 (40.2%)	<0.001	3,268 (41.6%)
Died in hospital n (%)	412 (3.0%)	284 (2.2%)	<0.001	227 (2.7%)	173 (1.9%)	0.001	80 (1.4%)

QAS time to triage based on 80194; QAS offload time based on 80184; QAS ED LOS based on 80191;
ED time to see Dr based on 261485 presentations; ED LOS based on 285425 presentations;
In-hospital mortality based on last admission of 49008 people

Table 4. Summary of time series ARIMA modelling testing the effect of opening ED on offload time, ED length of stay and access block.

Model Summary	**Outcome**		
	% offload time > 30 mins	**ED LOS**	**% access block**
Hospital A			
R squared	0.098	0.060	0.142
MAPE	82.5	10.6	20.6
Nomalised BIC	3.7	7.0	4.6
Estimated Intervention effect	0.54	5.39	5.13
Standard Error	0.69	3.13	1.05
T test statistic	0.79	1.72	4.91
P value	0.432	0.086	<0.001
Hospital B			
R squared	0.34	0.32	0.47
MAPE	84.8	12.05	47.02
Nomalised BIC	4.90	6.8	4.96
Estimated Intervention effect	12.44	29.99	18.32
Standard Error	1.42	3.58	1.64
T test statistic	8.74	8.37	11.15
P value	<0.001	<0.001	<0.001

ARIMA: Autoregressive Integrated Moving Average; MAPE: Mean Absolute Percentage Error; BIC: Bayesian Information Criteria; Estimated Intervention effect: estimated change in outcome measures after intervention compared to before ie., time of opening the new ED; values less than 1 indicate reduction.

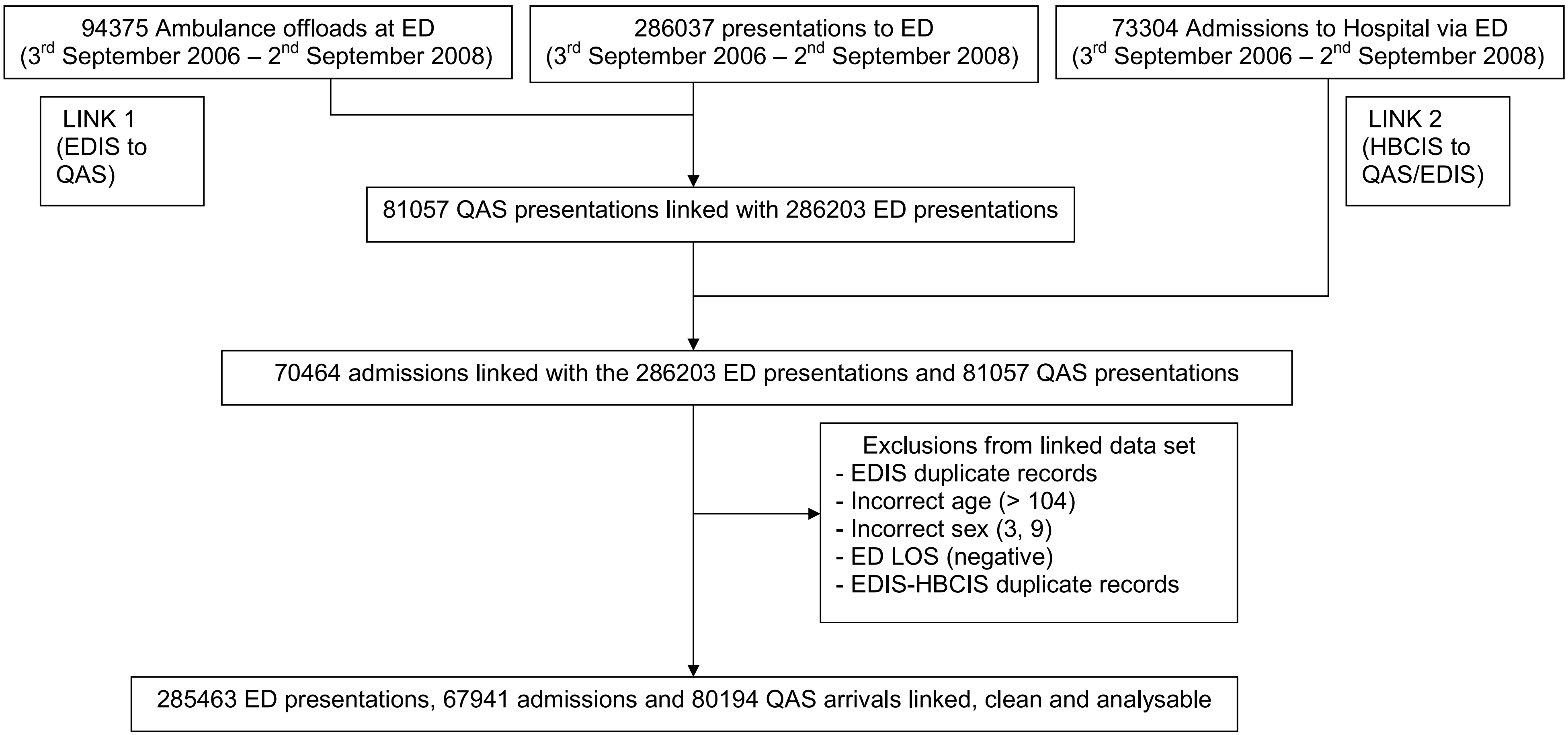

Figure 1. Data inclusion flow diagram: ambulance service and three hospitals; two year study period

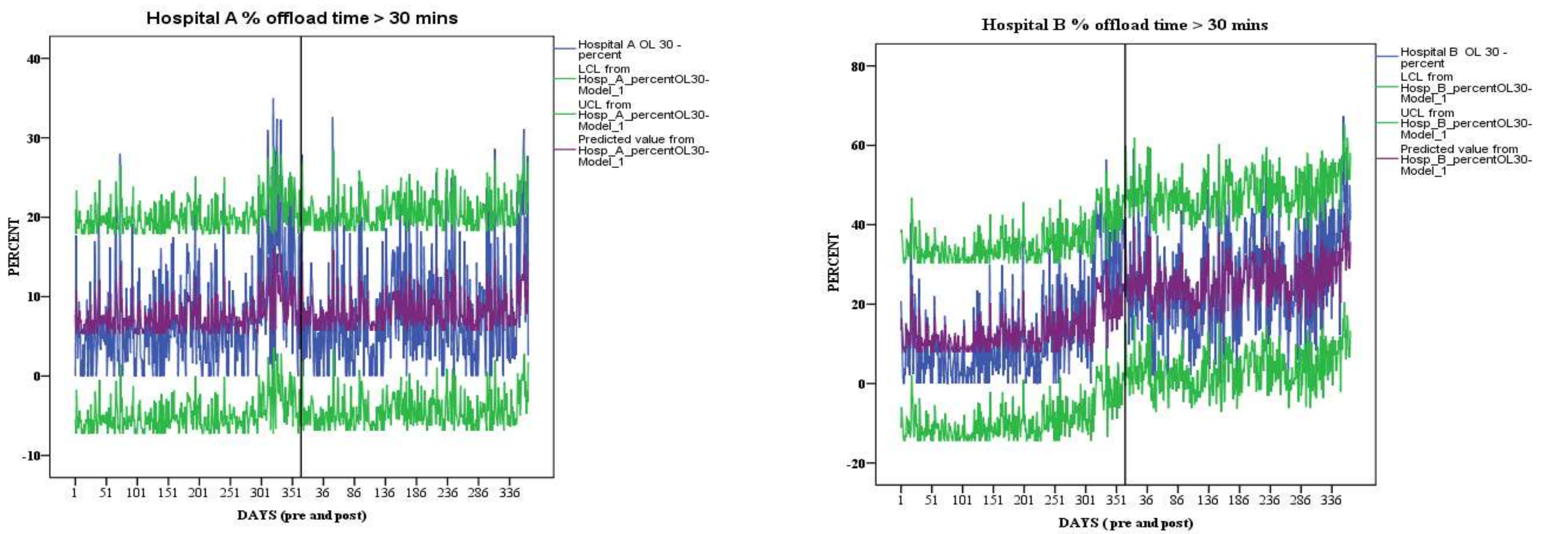

Figure 2. % Ambulance offload time exceeding 30 mins: Hospital A and Hospital B

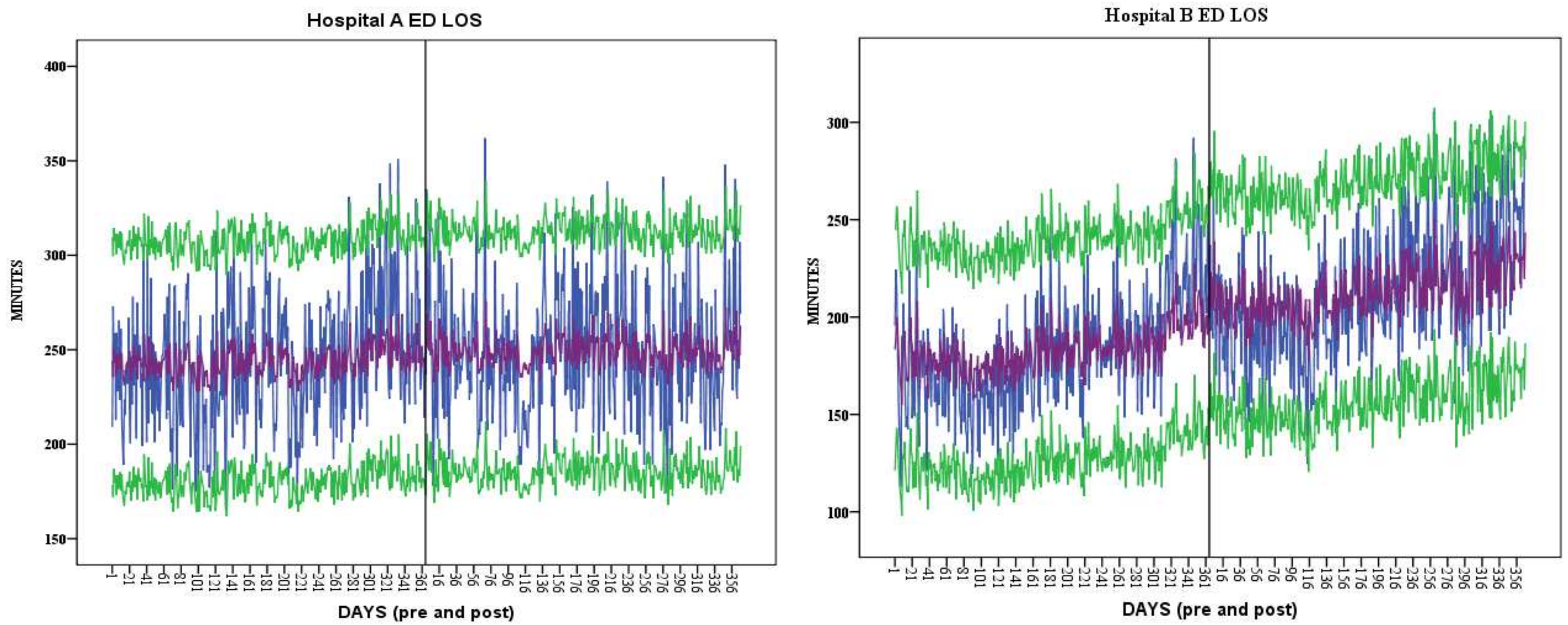

Figure 3. ED Length of Stay: Hospital A and Hospital B

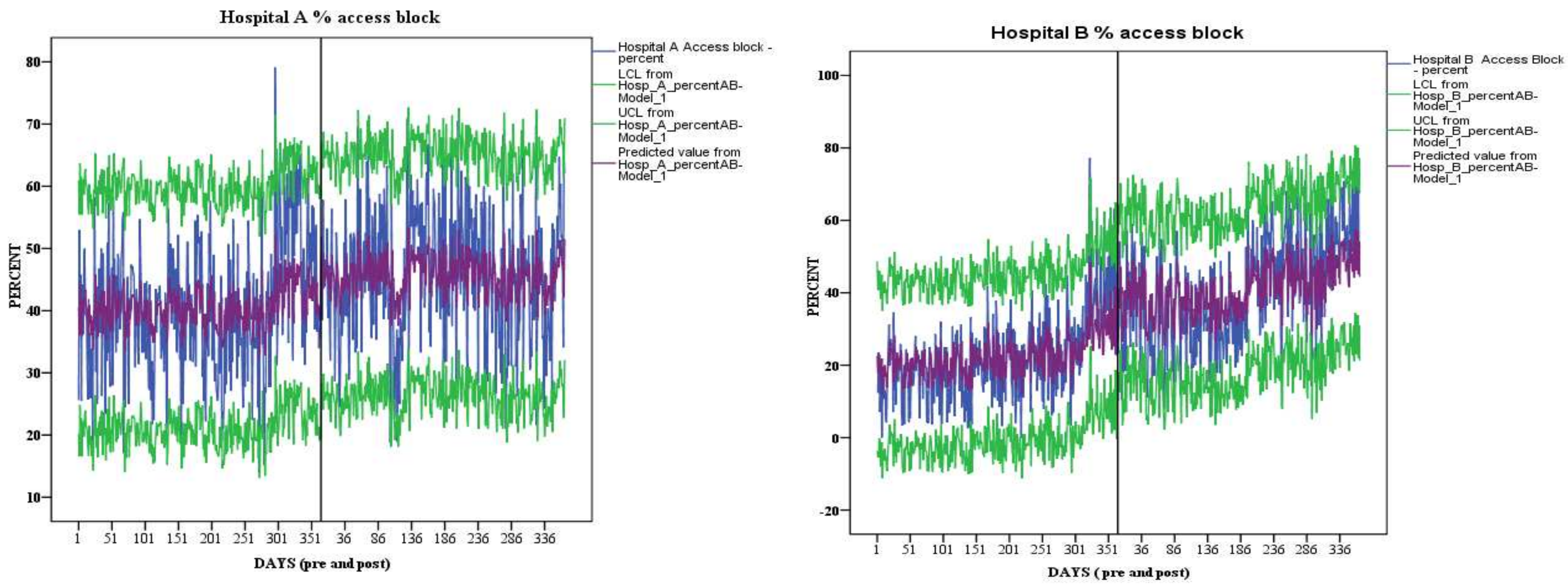

Figure 4. % Access Block: Hospital A and Hospital B.